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ACOUSTIC INTERFERENCE IN SHORT-TERM MEMORY IN CHILDREN

BY

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Acoustic Interference in Short-term Memory in Children" submitted by David E. Blackmore in partial fulfillment of the requirements for the degree of Master of Education.

ABSTRACT

The effects of four variables in short-term memory in children (acoustic similarity, list length, presentation rate, and grade level) were studied using a serial list learning task and immediate recall. The acoustic similarity was introduced by constructing serial lists of letters randomly selected from a pool of acoustically dissimilar letters (H, D, J, L, Q, R, W) or a pool of acoustically similar letters (B, C, D, G, P, T, V). The remaining variables were assigned the following parameters: presentation rate (.33, 1.00, and 2.00 seconds per item), list length (3, 4, and 5 items per list), and grade level (Grades 3 and 5). The data were collected from 156 subjects (78 subjects per grade) using a repeated measures design such that each S within each grade level participated in every condition. Three repetitions of each condition (a total of 3(2x3x3) = 54 experimental trials) were presented sequentially in a random order to a whole class simultaneously by means of a 16-mm film projector. The data were collected by subject written recall.

The results indicated that all four variables were significant factors in a child's learning processes. A greater number of recall errors were made on the acoustically similar lists than on the acoustically dissimilar lists. As the list length increased from three to five items, the number of recall errors also increased. As the presentation rate was increased from 2.00 to .33 seconds per item, the number of recall errors, again, increased. Finally, the Grade Three subjects made a greater number of recall errors than the Grade Five subjects. These results indicate that the organization of stimuli to be learned should be such as to avoid acoustic interference, especially in the lower grades.

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CHAPTER I

INTRODUCTION

The importance of acoustic similarity in studies of short-term memory (STM) was first demonstrated by Conrad (1962, 1964). Studying intrusion errors in the immediate recall of lists of six letters, Conrad found that letters ending with an "ē" sound (B, C, P, T, V) tend to be confused with each other and letters beginning with a "short e" sound (F, M, N, S, X) also tend to be confused. The confusion of similar sounding phonemes during the encoding of material to be remembered has become known as acoustic interference. Conrad's studies generated considerable interest and a great deal of subsequent research.

Acoustic similarity has been shown to create interference in STM with words (Conrad, 1963; Baddeley, 1966), letters (Conrad & Hull, 1964; Conrad, Freeman & Hull, 1965), nonsense syllables (Adams, 1967), and digits (Wickelgren, 1965a). Acoustic interference has been demonstrated to be present in STM both when the stimuli are presented visually (Conrad, 1962, 1963, 1964; Conrad & Hull, 1964) and auditorily (Baddeley, 1964; Wickelgren, 1965a, 1965b). On the basis of this latter finding, Wickelgren (1965a) has suggested that a short-term store (STS) encoding may be carried out in an acoustic fashion. This has very important implications for theories of memory (Sperling & Speelman, 1970) and for learning theory generally.

To date, there has been no investigation of developmental trends in acoustic interference, nor has there been any attempt to study acoustic interference effects in educational situations. The present study was designed to provide some initial insight into the nature of

acoustic interference in a simple learning task with grade school children. The task selected was the serial recall of lists which were made up of either acoustically similar letters (B, C, D, G, P, T, V) or acoustically dissimilar letters (W, H, D, L, Q, R, J).

Many variables have been shown to affect acoustic interference in the serial learning of word lists. A search of the literature was made, therefore, to determine how these variables interact with acoustic similarity and thus, how they should be controlled. The findings of the resulting literature search are presented and discussed in Chapter II, The Review of Related Literature, which takes the form of a summary and integration of 26 studies. The remainder of the thesis is organized as follows. Chapter III, Basis of Experimental Design, considers the implications of the findings discussed in Chapter II and develops the hypotheses. Chapter IV presents a discussion of the methodology used in the experimental task and the method of analysis employed. Chapter V presents the results of the experiment and Chapter VI is a discussion of the results. Chapter VII is a summary and commentary of educational relevance of the experimental results.

CHAPTER II

REVIEW OF RELATED LITERATURE

The first experimental study of memory was done by Ebbinghaus (1913). He recognized that responses which are equally available in memory at a given moment of time may not be equally available at a later time.

Memory may be thought of, as it has been traditionally, as a wholly inclusive monad (Melton, 1963; Postman, 1964); a dichotomy involving short-term memory (STM) and long-term memory (LTM); or a triad involving a sensory register, a short-term store (STS) and a long-term store (LTS) (Atkinson & Shiffrin, 1968). The arguments against dichotomizing memory rely mainly on the notion that a single process theory is more parsimonious than a dual process theory. In terms of physiological research (Milner, 1959, 1966, 1968), however, there is evidence supporting a dichotomy in memory. In research on verbal learning a dichotomy is shown to exist in that distinct laws seem to be operating separately in STM and LTM (Adams, 1967). Two differences between STM and LTM appear to be capacity, where STM capacity is said to be smaller than LTM (Miller, 1956), and interference, where LTM and STM respond to different kinds of interference (Conrad, 1964; Conrad & Hull, 1964; Baddeley, 1964, 1966; Wickelgren, 1965a, 1965b; Baddeley & Dale, 1966). A third component of memory, the sensory store, has been demonstrated by Sperling (1960, 1963, 1967). Although the purpose of this thesis research is not to argue the existence of two or more components of memory, it is vital to understand

that STM is an important and integral part of the overall memory system.

As mentioned earlier, acoustic interference is considered to be the confusion of similar sounding phonemes during the encoding of material to be remembered. Consequently, a string or list of acoustically similar items will be less well recalled than a list of acoustically different items. The conditions under which acoustic interference has been shown to exist are found in Table 1, which summarizes the experimental procedure of 26 different studies in which acoustic interference in STM has been studied. Breaking down the research designs into three variables (acquisition of stimuli, retention of stimuli, and retrieval of stimuli), allows each variable to be evaluated separately in terms of factors within each variable which appear to affect acoustic interference in STM.

Stimulus Type. Acoustic interference can occur when letters, words, varying length strings of letters, or digits are used as stimuli (See Table 1, Acquisition Stimulus Type). This wide range of stimuli in which acoustic similarity causes interference suggests that the vast majority of verbal learning tasks are subject to this type of interference and, as such, acoustic interference is probably a basic property of the encoding process.

Presentation Mode. Acoustic interference appears to be independent of the presentation mode (visual or auditory). The fact that written stimuli, which are perceived in a visual mode, have been shown to be subject to acoustic interference indicates that an acoustic process is involved either in learning or recall.

			ACQUISITION			
STUDY	STIMULUS TYPE	MODE OF PRESENTATION	PRESENTATION PARADIGM	RATE OF PRESENTATION*	PRESENTATION SEQUENCE	ITEMS/LIST
1	letters	visual	serial	.75	sequential	6
2	letters	visual	serial	.75	sequential	6
3	letters	visual	serial	.75	sequential	6
4	words	visual	serial	1.00	sequential	5
5	letters	visual	serial	.75	sequential	6
6	letters	visual	serial	.75	sequential	6
7	letters	visual	serial	.50	sequential	6
	letters	visual	serial	1.00	sequential	6
8	letters	visual	serial	>1.00	sequential	4
	letters	visual	serial	>1.00	sequential	4
9	letters	visual	serial	>1.00	sequential	5
10	words	auditory	serial	1.00	sequential	5
11	adjectives	auditory	paired-associate	1.00 2.00	sequential	3 pairs
12	words	auditory	serial	1.00	sequential	5
	words	auditory	serial	1.00	sequential	5
13	letters numbers	auditory	serial	.75	sequential	8
14	letters	auditory	serial	.50	sequential	4
15	letters	auditory	serial	.50	sequential	1
16	letters	auditory	serial	.50	sequential	1

ACQUISITION

STUDY	STIMULUS TYPE	MODE OF PRESENTATION	PRESENTATION PARADIGM	RATE OF PRESENTATION*	PRESENTATION SEQUENCE	ITEMS/LIST
17	words	visual	serial	1.00	simultaneous	3
18	words	aural	serial	.60	sequential	16-21
19 a)	letter bigrams or tetragrams or trigrams	visual	serial	4.00	simultaneous	2,3, or 4
b)	see 19a	visual	serial	.50	sequential	2,3, or 4
c)	see 19a	visual	serial	.50 or 2.00	sequential or simultaneous	4 4
20	tetragrams	visual	serial	.50 or 2.00	sequential or simultaneous	4 4
21	words	visual	paired associate	2.00	sequential	6 pairs
22	words	auditory	serial	2.00	sequential	16
23	letters	visual or auditory	serial	.33 or 1.00	sequential	6 or 8
24	letters and words	visual	serial	1.00	simultaneous	3
25	digits and letters	visual	serial	1.00	sequential	8
26	words	visual	serial	3.00	simultaneous	3

	RETENTION		RETRIEVAL		
STUDY	RETENTION PERIOD**	INTERPOLATED ACTIVITY	METHOD	ACOUSTIC INTERFERENCE	AUTHOR
1	0	---	recall	yes	Conrad (1962)
2	0	---	recall	yes	Conrad (1964)
3	0	---	recall	yes	Conrad (1965)
4	0	---	recall	yes	Conrad (1963)
5	0	---	recall	yes	Conrad & Hull (1964)
6	0	---	recall	yes	Conrad, Freeman & Hull (1965)
7	0	---	recall	yes	Conrad, Baddeley & Hull (1966)
8	2.4	read digits	recall	yes	Conrad (1967)
	7.2	read digits	recall	no	
9	0	---	recall	yes	Conrad & Rush (1965)
10	0	---	recall	yes	Baddeley (1964)
11	10	---	recall	no	Baddeley & Dale (1966)
12	0	---	recall	yes	Baddeley (1966)
	0	---	recall	yes	
13	0	---	recall	yes	Wickelgren (1965a)
14	4.0	8-item lists	recall	yes	Wickelgren (1965b)
15	6.0	12-item list	recognition	yes	Wickelgren (1966a)
16	varied	0,4,8, or 16 PI and RI	recall	yes	Wickelgren (1966b)
17	0,4,8, or 16	backward counting	recall	no	Henley, Noyes & Deese (1968)

	RETENTION		RETRIEVAL		
STUDY	RETENTION PERIOD**	INTERPOLATED ACTIVITY	METHOD	ACOUSTIC INTERFERENCE	AUTHOR
18	0	---	recognition	yes	Reicher, Ligon & Conrad (1969)
19 a)	0,5,10,15, or 30	words, digits	recall	no	Adams, Thorsheim & McIntyre (1969a)
b)	0	---	recall	yes	
c)	0,5,10,15, or 30	read digits	recall	at 0, 15, and 30 seconds	
20	0,5,10,15, or 30	read digits	recall	at 0 seconds in PI	Adams, Thorsheim & McIntyre (1969b)
21	0	---	probe	no for RI	Bruce & Murdock (1968)
22	0	---	probe	yes, up to 22-sec	Kintsch & Buschke (1969)
23	0	---	recall	yes, at .33-sec	Laughery & Pinkus (1966)
24	20	color naming	recall	yes	Wickens & Eckler (1968)
25	0	---	recall	yes	Hintzman (1965)
26	3	6 item list	recall	yes	Dale & Gregory (1966)

*reported in seconds per item

**reported in seconds

TABLE 1

DESIGN SUMMARY OF TWENTY-SIX EXPERIMENTS
STUDYING ACOUSTIC INTERFERENCE
IN SHORT-TERM MEMORY

Presentation Method. The two stimulus presentation methods which are most commonly used in studying acoustic interference are serial presentation and paired-associate presentation. In the serial method a list of stimuli is presented to a subject who is then asked to recall the list in the order of its presentation. In paired-associate learning a stimulus term is displayed and the subject is asked to recall the response term. After the anticipation interval, the response term is shown to the subject who may then study the correct response in order to prepare himself for the following trials. All studies presented in Table 1 used one of these two procedures. In only one case did paired-associate learning produce acoustic interference. However, as there are very few studies dealing with paired-associate learning and acoustic similarity, the reasons for the lack of acoustic interference is not clear.

It is possible, however, that the long presentation rate involved in the paired-associate task and, in the case of experiment number 11 (Baddeley & Dale, 1966), a long retention interval would tend to break down the acoustic interference by allowing rehearsal by the subject. Bruce and Murdock (1968) demonstrated acoustic interference using the paired-associate presentation method by using a retention interval of zero seconds, but only in the proactive inhibition conditions. The main body of literature indicates that acoustic interference can best be examined within the serial learning paradigm.

Presentation Rate. The rate at which the stimuli were presented to the subjects and still produced acoustic interference varied from

.33 seconds per item to 2.00 seconds per item (See Table 1). the most reliable presentation rates appear to be from .5 to 1.00 seconds per item. Acoustic interference appears to be minimal in learning tasks which use a presentation rate longer than 2.00 seconds per item. This finding suggests that acoustic encoding is completed before 2 seconds have elapsed. However, this time factor may depend on the degree of acoustic similarity and the resulting acoustic interference. The processing time to encode stimuli which create acoustic interference appears to be longer than the time needed to encode stimuli which are not acoustically similar. Presentation rates are a critical factor in producing acoustic interference and should, therefore, be closely controlled.

Presentation Sequence. Two types of stimulus presentation sequences were used in the studies examined in Table 1: (1) the stimuli were presented sequentially, one stimulus at a time and (2) the stimuli were presented simultaneously. Adams, Thorsheim and McIntyre (1969) reported observing acoustic interference using sequential presentation only when recall was immediate. However, they also observed acoustic interference with simultaneous presentation but only after a retention period of twenty seconds. The majority of the studies examining acoustic interference generally utilize the sequential paradigm.

List Length. Acoustic interference has been demonstrated over a wide range of list lengths (Table 1). The range is from 2 to 21 items per list. The large range in list lengths would tend to indicate that acoustic interference will occur independent of list length

although the amount of acoustic similarity within a list will determine the amount of acoustic interference obtained. List length is, therefore, important in that longer lists will allow a larger quantity of acoustic similarity to be present. However, if the list exceeds the subject's learning capacity under a non-acoustically similar condition, then the number and type of errors made on an experimental list of equal size are compounded by the extension of the subject's ability as well as the acoustic interference. Thus, in order to obtain a reliable measure of acoustic interference, the list length should not exceed the subject's ability under a non-experimental or acoustically non-similar condition.

Retention Interval. The retention period (length of time between acquisition and recall) appears to be very critical. Predominately, the results in Table 1 indicate that the majority of studies were not able to observe acoustic interference if recall did not immediately follow the acquisition of stimulus material. In four studies, acoustic interference was reported up to four seconds following acquisition and up to six seconds following acquisition for a recognition task. It would appear, therefore, that acoustic variables, with regard to their role in encoding, have a very short life. A long retention interval gives the subject time to rehearse the stimuli, which attenuates acoustic interference. To prevent the rehearsal of stimuli, an interpolated activity is sometimes used. This activity may be comprised of numerical problems, second list learning, verbal speech, or any activity which

is intended not to interfere with the experimental task. While studying acoustic interference, however, it is difficult to initiate such a task, since most material which could be used is itself subject to acoustic variables and would cause inter-list interference. Consequently, immediate recall of the experimental list provides the best experimental procedure for assessing the degree of acoustic interference in learning tasks.

Retrieval Techniques. All three forms of retrieval, total recall, probe technique, and recognition tasks, were able to record acoustic interference. Total list recall requires the subject to recall the entire list of stimuli. The probe technique is when one item from the list is selected and given to the subject, who is asked to give the next item in the list. In the recognition task, the subject is given an item and asked whether that item appeared in the list which was previously presented. Total list recall, however, provides the greatest amount of information with regard to the nature and type of errors produced by both inter-list and intra-list interference. Consequently, total list recall is the more widely used method.

Summary of Design Variables

It would seem that to demonstrate acoustic interference in short-term memory in adults, the stimulus materials may be words, letters, or digits presented either visually or auditorily. A serial presentation method, in which each item is presented sequentially at a rate of .33 seconds per item to 1.5 seconds per item should be used. The number of items per list may vary from 2 to 21 depending on the type of recall

task employed. The retention interval may vary from zero to five seconds, with the best results being reported at zero seconds. If recall is not immediate, an interpolated activity task which prevents rehearsal and does not interfere with the experimental variables may be incorporated. Recall of the stimulus list by the subject may be by total recall (written or oral), probe technique, or by a recognition task. These variables must be taken into consideration when designing an experiment which is to study acoustic interference resulting from intralist acoustic similarity.

Acoustic Interference in Children

There has been no systematic investigation of the developmental aspects of short-term memory or long-term memory in children. Initial studies with children on the effect of acoustic interference on memory are, probably, best designed by taking into account experimental variables which are significant with adult subjects.

The purpose of this thesis research is threefold: (1) to consolidate the factors which have been shown to be of significance in studies which have investigated acoustic interference in short-term memory in adults; (2) to determine if acoustic interference exists with children at two grade levels (Grades 3 and 5); and (3) to examine in what ways acoustic interference effects in children are different from similar effects found in adults.

CHAPTER III

DESIGN RATIONALE

The purpose of this chapter is to outline the rationale for the experimental design used in this study and to state the hypotheses resulting from Chapter II. As the number of variables that have been shown to affect acoustic interference is fairly substantial, only a limited number of the most significant variables will be incorporated in the design. The remaining variables will be held constant at a level or condition selected on the basis of the information reported in Chapter II.

Experimental Factors

The factors that seem of most interest in the study of acoustic interference in children are presentation rate, retention interval, stimulus materials, presentation mode, list length, and age. A complete study would incorporate these seven basic experimental factors For this study, however, anticipation of some of the results by considering previous research with adults led to a design utilizing only four factors, acoustic similarity, presentation rate, list length, and age, as the main variables. The other three variables, presentation mode, retention time, and stimulus materials, were held constant.

Retention Interval. The retention interval was assigned a value of zero seconds or, in other words, recall was immediately following the stimulus list presentation. This was based on the finding that acoustic interference was best reported at this interval, as well

as having the added advantage of eliminating the need to control rehearsal during the retention interval.

Presentation Mode. Acoustic interference is reported whether the presentation mode is visual or auditory. For convenience, the visual mode was employed. By presenting the stimuli visually using a 16-mm film and projector, the experiment could be administered to whole classes simultaneously. This method of presentation provides a convenient method of accurately controlling the presentation rate of the stimuli. The projector ran at a constant speed of 24 frames per second. By varying the number of frames per item shown to the subject, the presentation rate was easily controlled. For example, a stimulus presented for eight frames would be seen by the subject for one-third of a second. Similarly, a stimulus presented for 24 frames would appear for one second and one presented for 48 frames would be viewed for two seconds. Therefore, the visual presentation mode was selected because the film could be easily fabricated, the presentation rates could be accurately controlled, and the experiment could be administered to groups.

Stimulus Type. Two sets of letters were selected. One set was acoustically similar (B, C, D, G, P, T, V) and one set was acoustically dissimilar (D, H, J, L, Q, R, W). All lists consisted of randomly selected letters from one of these two sets. Only intralist interference (interference between items within a list) was studied as opposed to interlist interference (interference between lists). The use of letters as stimuli was used in order to insure that the

stimulus materials would be within the vocabulary range of all subjects.

Acoustic Similarity. Two levels of acoustic similarity were assigned to the stimulus materials: high (stimulus lists were selected from the acoustically similar letter set) and low (stimulus lists were selected from the acoustically dissimilar letter set). The low level of acoustic similarity lists served as the control group. Each level of presentation rate, list length, and grade level had equal numbers of high and low (control) acoustically similar lists.

A short-term memory task using an acoustically similar stimulus list is expected to produce a greater number of recall errors than an acoustically dissimilar stimulus list. This finding has been demonstrated by Conrad (1964), Conrad & Hull (1964), Conrad, Freeman & Hull (1965), Wickelgren (1965a, 1965b), and others. All subjects used in these studies were adults. If acoustic similarity creates interference in learning in children, then a difference between the acoustically similar condition and the acoustically dissimilar condition should also exist.

List Length. Three levels of list length were used in this experiment: three, four, or five items per list. A limit of five items per list was employed in order to maintain a list length which could be learned by children. The length of two items per list was excluded on the basis that acoustic interference effects might not be reliably demonstrated with such a short list. The maximum of five items per list was chosen by virtue of its being the lower limit of the

average adult memory range of 7 ± 2 chunks of information (Miller, 1956).

In adults, there is a reliable relationship between list length and the number of errors made during recall. As the length of the stimulus list increases, the number of errors made during recall increases. This finding also holds when acoustic similarity is introduced as a variable in the stimulus list, except an even greater number of errors occur (Laughery & Pinkus, 1966). Consequently, if acoustic interference is observed in children, a similar finding is expected.

Presentation Rate. Three levels were assigned to the presentation rate variable: .33 seconds per item, 1 second per item, and 2 seconds per item. These levels were selected on the basis of the findings discussed in Chapter II. Acoustic interference is initially observed at the presentation rate of three items per second. Increased interference is observed at the rate of one item per second. However, at the presentation rate of one item per two seconds, the amount of observed interference decreases. Laughery and Pinkus (1966) demonstrated this finding with adults. However, no evidence of similar results has been reported using children as subjects. If acoustic similarity is demonstrated to create interference in learning for children, a similar finding would be expected. However, this would only be true if there are no differences demonstrated between adults and children in the way in which acoustic interference influences their learning behavior.

Grade Level. Two grade levels were selected: Grade Three and Grade Five. Grade Three was chosen because it was the grade closest

to the initial "letter learning" process which would be able to comprehend the experimental procedure. Grade Five was chosen to allow an age contrast with Grade Three. Children develop and improve their cognitive processes rapidly during the early grade levels. If the ability to become efficient in overcoming acoustic interference is a factor of development, then a difference in the number of errors made during recall would be expected. There is no evidence that the ability to overcome acoustic interference is developmental in nature. However, Hansen (1965) demonstrated that ten year old children were better able to handle short-term memory tasks at a given presentation rate (either one second per item or three seconds per item) than five year old children. This increase in memory as a factor of age would suggest that older subjects (Grade 5) would recall a larger number of correct items on all conditions (presentation rate, list length, and acoustic similarity).

Hypotheses

Taking into consideration that acoustic variables have not been investigated in children, the following hypotheses were proposed from the information obtained from adult subjects.

Experimental Hypotheses

1. There will be a greater number of recall errors observed on the acoustically similar trials than on the acoustically dissimilar trials for both grade levels.
2. As the length of the stimulus list increases, the number

of observed errors will increase for both grade levels.

3. The number of errors will increase as the presentation rate increases for both grade levels.
4. A list length by presentation rate interaction is predicted where the error differences between the different list lengths at different presentation rates will not be equal.
5. An acoustic similarity by list length interaction is expected where the error difference between the high and low acoustic conditions for the longest list will be greater than the error difference obtained between the high and low acoustic condition for the shortest list.
6. An acoustic similarity by list length by presentation rate interaction is predicted for all subjects where the error differences obtained between the high and low acoustic conditions, at the fastest presentation rate and the longest list length will be larger than the observed error difference between the high and low acoustic conditions at the slowest presentation rate and the shortest list.
7. There will be a greater number of recall errors for Grade Three children over all conditions than for Grade Five children.

CHAPTER IV

METHODOLOGY

The basic design used in this experiment was a 2 x 2 x 3 x 3 factorial design with the last three factors (acoustic similarity, presentation rate, and list length) being repeated measures within grade level (See Figure 1).

Subjects

Students enrolled in Grades Three and Five in the Edmonton Public School System during the 1970-71 school term were used as subjects. Four classes of each grade were tested. The schools used were allocated by the Research Division of the Edmonton Public School Board. The Grade Three subjects were obtained from two different middle Social Economic Status (SES) schools. Three classes (the entire Grade Three population for that school) were obtained from Gold Bar Public School and one class from Westbrook Public School. The Grade Five subjects were also obtained from two middle SES schools. Three classes (the entire Grade Five enrollment for that school) were obtained from Richard Secord Public School and one class from Westbrook Public School.

Apparatus

Stimuli were presented to an entire class by means of a 16-mm film and projector. The timing of the stimulus presentation was controlled by the number of frames shown for each stimulus. The film projector ran at a constant speed of 24 frames per second (See Appendix A

			Acoustic Similarity	High			Low		
				Presentation Rate					
				.33	1.00	2.00	.33	1.00	2.00
GRADE	3	LIST LENGTH	3						
			4						
			5						
	5	LIST LENGTH	3						
			4						
			5						

FIGURE 1

EXPERIMENTAL DESIGN
2 x 2 x 3 x 3 FACTORIAL WITH THE LAST
THREE FACTORS REPEATED

for a detailed explanation on the production of the film). Responses were recorded by the subjects in answer booklets following each trial.

Procedure

Each class was presented a seventeen minute film on which there were 68 trials. The 68 trials were made up of three repetitions of the 2 x 3 x 3 factorial set (two levels of acoustic similarity, three list lengths, and three presentation rates) with different lists selected randomly from the appropriate stimulus set. This accounts for 3 x 18 or 54 trials. The additional 14 trials were perceptual control trials on which each item (a letter) was presented alone for .33 seconds. The subjects were then asked to copy down what they observed. Any subject who made three or more perceptual errors was considered to have perceptual difficulty with the stimuli and, subsequently, had his data withdrawn from analysis. At first, it appeared to be a large number of trials to administer to a Grade Three subject. However, as both presentation time and list length were randomly varied and because the subject was kept busy by the recall task, interest in the task was maintained throughout the testing session. As an incentive to the child to pay close attention to the task, a prize, consisting of a chocolate bar was promised and presented at the end of the session for doing a good job. All children participating received this prize.

Each trial consisted of the presentation of the list to be learned in sequential order, at the appropriate presentation rate, followed by an eight second recall period which was signified to the subject by the film turning a light green. After eight seconds, the sub-

jects were instructed verbally by the experimenter to turn the page of their answer booklets and get ready for the next trial. The film turned red from the light green for three seconds as a visual cue to get ready. This supplemented the auditory cue given by the experimenter. The total recall period was 11 seconds per trial.

The procedure was as follows. Instructions were given to the class. Four practice trials were then given, one at each presentation rate and of varying list lengths. The subjects were asked if there were any questions and the procedure was reviewed. The subjects watched the screen while the list of letters to be learned was presented until the screen turning green indicated that the list was finished. At that time, the subjects recalled the stimuli that were presented, in the order in which they were presented, and then turned the page of the answer booklet to the next page. The end of the recall period was signified by the film color change from light green to red and by the experimenter telling the subjects to turn the page and get ready for the next trial. A supply of pencils was given to each subject and no loss of trials resulted from broken pencils.

Analysis Procedure

Each subject's answer booklet was marked and the resulting information was transferred to a data sheet. Each data sheet indicated which items within each trial were correct or the nature of the error. The number of trials in which an error was made for each condition for each subject was then entered into an error matrix (Figure 2). The error matrix for each subject was then transferred to IBM cards and,

		List Length	Presentation Rate (Seconds per Item)		
			.33	1.00	2.00
Acoustic Similarity	High	3			
		4			
		5			
	Low	3			
		4			
		5			

FIGURE 2

ERROR TABULATION MATRIX

subsequently, analyzed using the BIOMED pack program BMD08V and the IBM 360/67 facilities at the University of Alberta. The results are discussed in Chapter V.

CHAPTER V

RESULTS

The results of 113 Grade Five students and 92 Grade Three students were obtained. Ten Grade Five subjects were dropped due to either their inability to follow instructions or because they made too many perceptual errors. Fourteen Grade Three subjects were dropped for similar reasons. As there was no significant difference among the Grade Five classes, one class was excluded from the analysis in order to facilitate the analysis procedure, thereby equating the *n* to 78 for both grades. A summary of the raw data, giving the number of errors obtained for each condition for each class (including the excluded Grade Five class) percentage errors and means and variances of each condition is located in Appendix C. All Grade Five results analyzed were obtained from Richard Secord Public School. All four Grade Three classes tested were included in the analysis. Table 2 contains a summary of the analysis of variance results. The results and *a priori* tests are presented in the order of main effects, homogeneity assumptions, first order interactions, second order interactions, and third order interactions. A summary of the results is given at the end of Chapter V.

Main Effects

All main effects (grade level, acoustic similarity, list length, and presentation rate) were significant ($p<.01$). The Grade Three subjects consistently made a greater number of recall errors (52%) than did the Grade Five subjects (35%) (See Figure 3). The differences in percentage of errors between high and low acoustic similarity conditions

Source	Error Term	F	SS	df	MS
G	S(G)	84.20**	194.49	1	194.49
A	SA(G)	316.85**	190.30	1	190.30
L	SL(G)	988.78**	1333.83	2	666.92
P	SP(G)	180.88**	273.63	2	136.81
S(G)			355.73	154	2.31
GA	SA(G)	0.37	0.22	1	0.22
GL	SL(G)	2.54	3.43	2	1.72
AL	SAL(G)	58.88**	45.55	2	22.78
GP	SP(G)	1.19	1.80	2	0.90
AP	SAP(G)	1.41	1.23	2	0.62
LP	SLP(G)	16.74**	32.72	4	8.18
SA(G)			92.49	154	0.60
SL(G)			207.74	308	0.67
SP(G)			232.96	308	0.76
GAL	SAL(G)	10.38**	9.68	2	4.84
GAP	SAP(G)	1.02	0.89	2	0.45
GLP	SLP(G)	4.72**	9.23	4	2.31
ALP	SALP(G)	13.72**	21.07	4	5.27
SAL(G)			143.50	308	0.47
SAP(G)			134.33	308	0.44
SLP(G)			300.92	616	0.49
GALP	SALP(G)	1.70	2.61	4	0.65
SALP(G)			236.54	616	0.38

G = Grade
A = Acoustic Similarity
L = List Length
P = Presentation Rate
S = Subjects
SS = Sum of Squares
df = Degrees of Freedom
MS = Mean Square
** = Significant at $p<.01$

TABLE 2

SUMMARY OF ANALYSIS OF VARIANCE

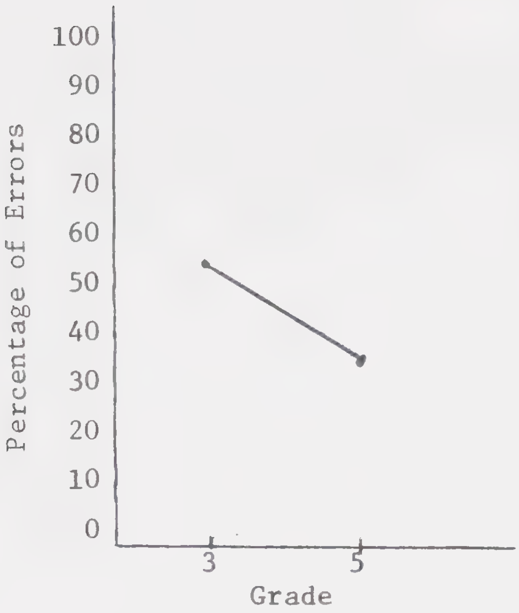


FIGURE 3

PERCENTAGE OF RECALL ERRORS
FOR GRADES THREE AND FIVE

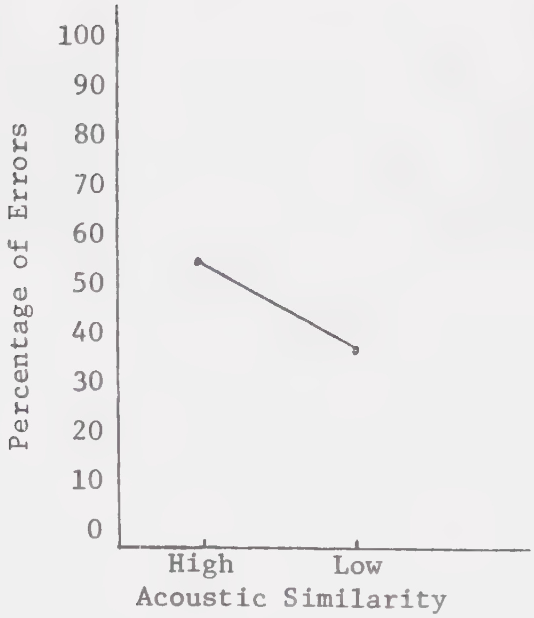


FIGURE 4

PERCENTAGE OF RECALL ERRORS
FOR HIGH AND LOW ACOUSTIC SIMILARITY

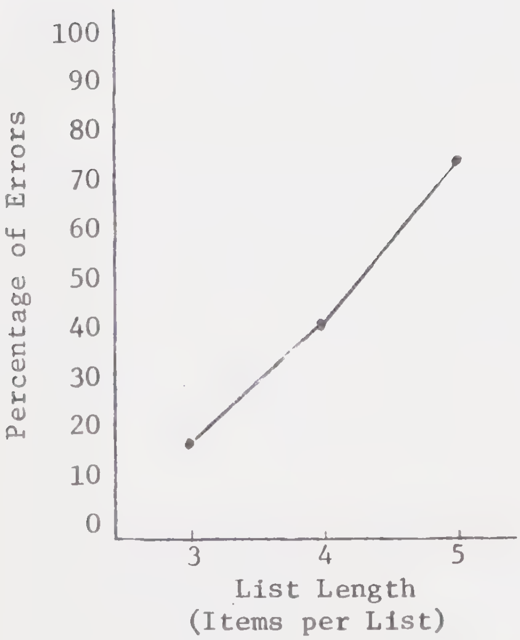


FIGURE 5

PERCENTAGE OF RECALL ERRORS
FOR THREE LIST LENGTHS

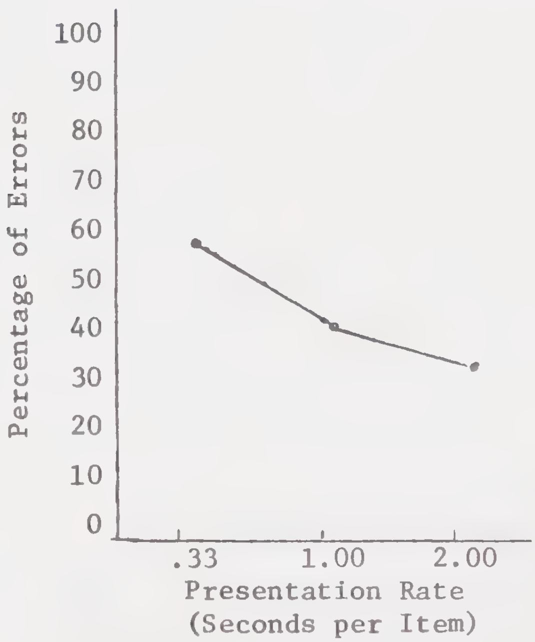


FIGURE 6

PERCENTAGE OF RECALL ERRORS
FOR THREE PRESENTATION RATES

was 17%, with the high condition producing the most errors (Figure 4). The list length results are presented in Figure 5. Seventeen percent errors were observed when the list contained three items, 40% when the list contained four items, and 73% when the list contained five items. A Newman-Keuls comparison of the means indicates that each mean is significantly different from each of the other two ($p<.01$). The results obtained from the three different presentation rates are presented in Figure 6. When the stimuli within a list were presented at the rate of .33 seconds per item, the subject made 57% recall errors. Forty percent recall errors were made by the subject when the stimuli were presented at one second per item and 33% recall errors when a two seconds per item presentation rate was used. A Newman-Keuls comparison was made on the presentation rate means. The results indicate that the .33 seconds per item rate differs significantly from the one and two second rates ($p<.01$) and the one second rate differs from the two second rate at the .05 level.

Assumptions of Homogeneity of Population Variance

Interactions which were significant are Grade Level by Acoustic Similarity (G x A), List Length by Presentation Rate (L x P), Grade Level by Acoustic Similarity by List Length (G x A x L), Grade Level by List Length by Presentation Rate (G x L x P), and Acoustic Similarity by List Length by Presentation Rate (A x L x P). These interactions are presented in Figures 8 through 12, respectively. A cursory glance at these figures reveals that the interactions may be result of a scaling effect as indicated by apparent ceiling and floor effects. The variances and means were plotted (Figure 8) in order to determine if a linear trend was present such that a transformation of the data and

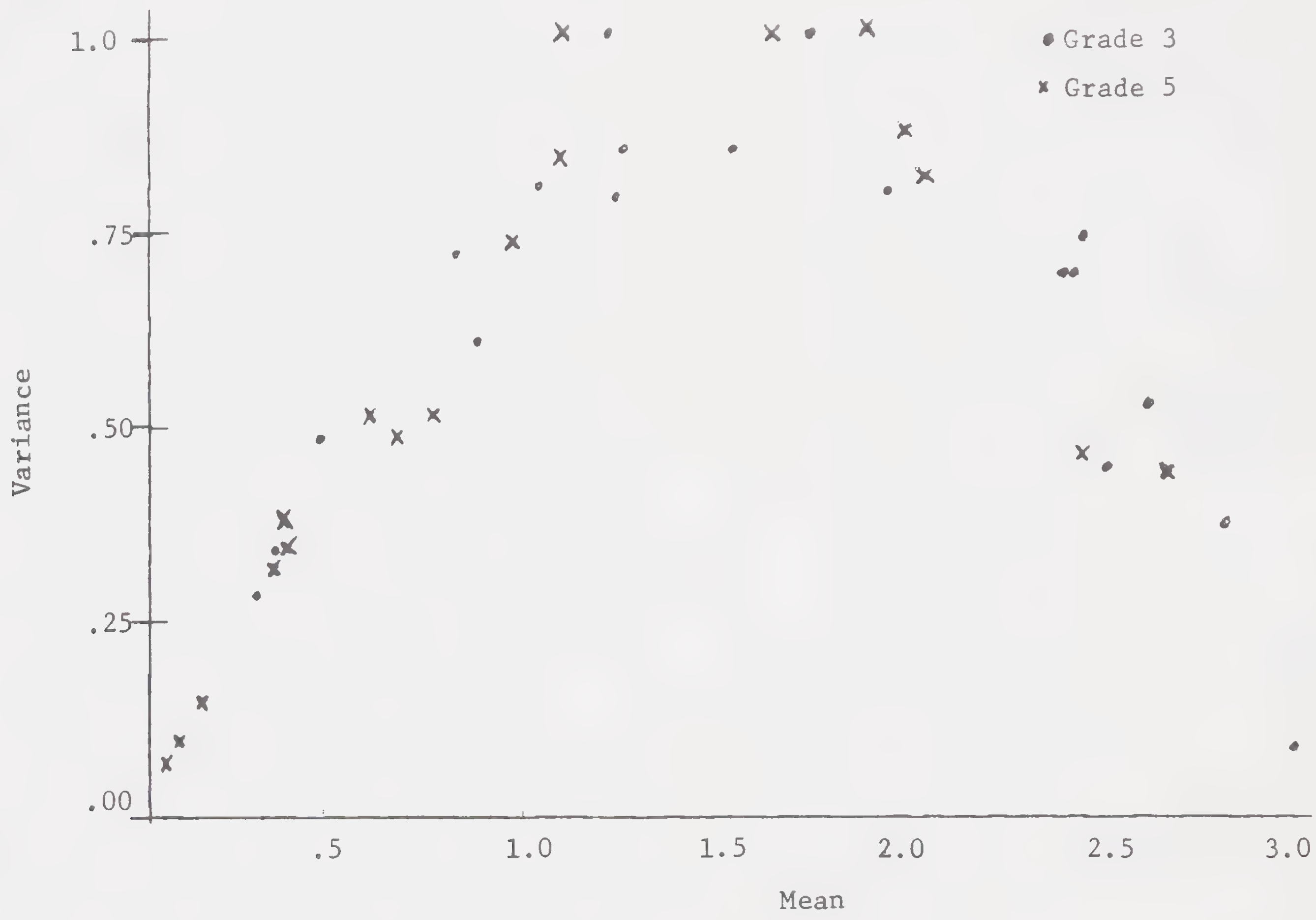


FIGURE 7

SCATTER PLOT OF THE GRADE MEANS VERSUS ERROR VARIANCES

subsequent re-analysis would be warranted. Clearly, no linear trend is present. A curvilinear relationship is apparent, but no appropriate monotonic transformation for these data exists (Kirk, 1968). The F_{max} statistic was then applied to the error variances in order to test the assumption of homogeneity of variance. F_{max} was significant ($p<.01$) for both grade levels, indicating that the variances are heterogeneous. Normally, the F distribution is robust with respect to violation of the assumption of homogeneity of variance with equal sample sizes. The variances, however, have been shown to be highly heterogeneous which may, therefore, increase the possibility of rejecting a null hypothesis which is true. Interactions resulting from possible scaling effects may be falsely significant. Keeping this in mind, the results of the aforementioned interactions are reported below.

First Order Interactions

A significant Acoustic Similarity by List Length interaction was obtained ($p<.01$). The percentage of errors for each list length for each acoustic similarity condition was plotted (Figure 8). As the list length increased from three to five items, the percentage of subject recall errors increased from 20 to 84 for the acoustically similar condition and from 15 to 62 for the acoustically dissimilar condition. A Scheffée comparison of means was applied. The results indicated that the difference of five percent between the low and high acoustic similarity conditions, when the list contains three items, was not significant. The differences between the high and

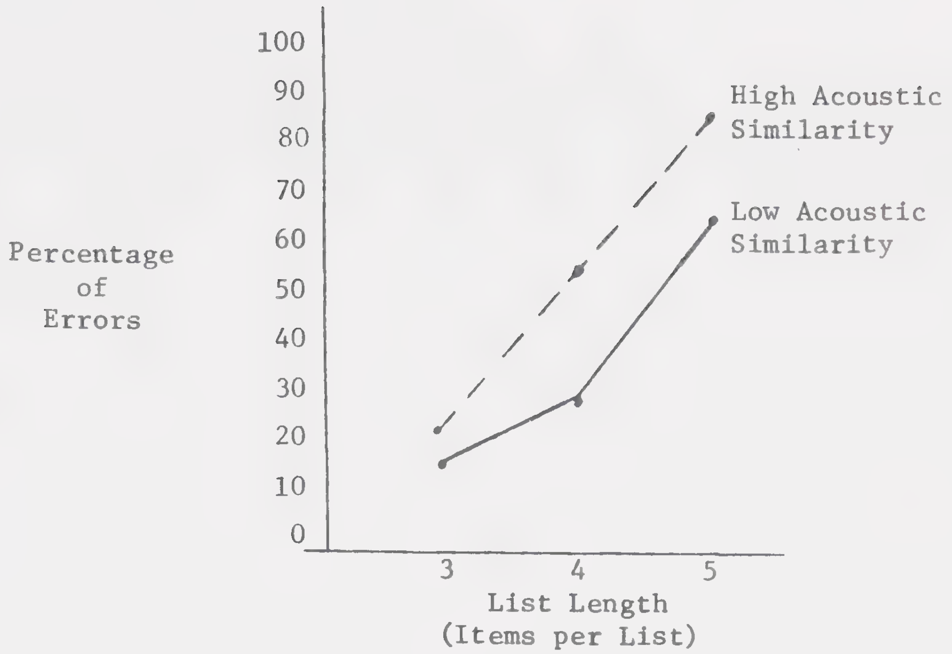


FIGURE 8

ACOUSTIC SIMILARITY BY LIST LENGTH INTERACTION

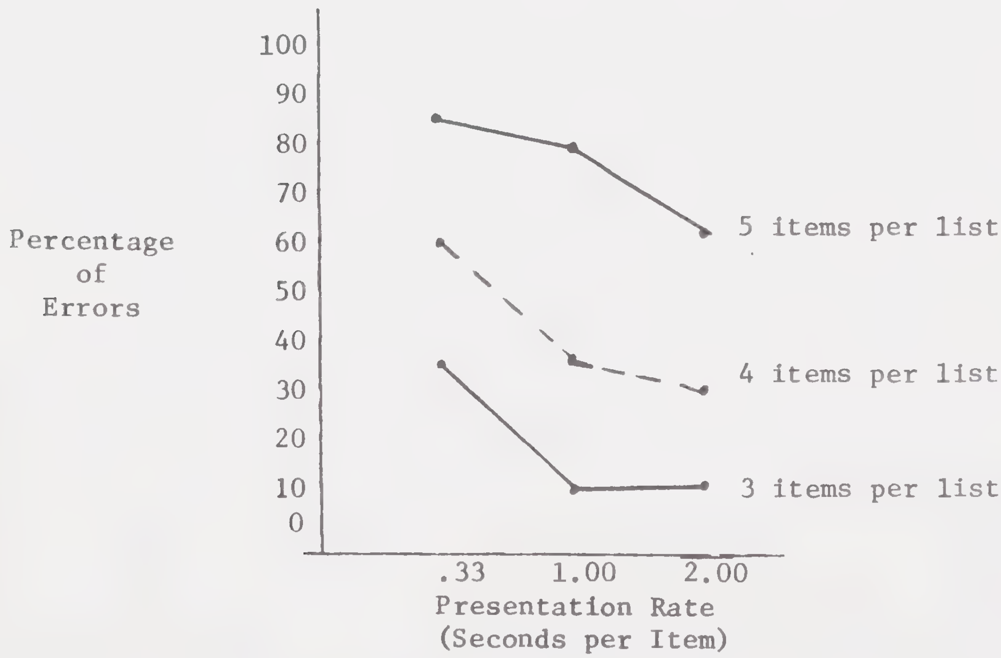


FIGURE 9

PRESENTATION RATE BY LIST LENGTH INTERACTION

low similarity conditions when the list contained four or five items was significant ($p<.01$). The difference observed between the high and low similarity three item list was significantly different than the differences obtained between the high and low similarity four or five item lists. The interactions caused by the differences in recall errors between the different list lengths and levels of similarity may be due to a floor effect.

The Presentation Rate by List Length interaction was significant. The percentage of errors for each list at each presentation rate is presented in Figure 9. Generally, as the list length and presentation rate increased the percentage of errors made by the subject increased. A Scheffée comparison of the means was made and the following results obtained. Each of the three list lengths differed significantly at each presentation rate ($p<.01$). Within lists containing three items, no significant difference was found between the 1.00 and 2.00 seconds per item rates. A similar finding was observed on the four item lists. With the five item list there was no significant difference between the .33 and 1.00 second rates, but there was a significant difference between the 2.00 second rate and the other two presentation rates. The difference in the increase in errors observed between the three and four item lists and the four and five item lists at the 1.00 second rate was signficant.

The interaction appears to indicate that difficulty encountered by the subject is greater at the 1.00 second presentation rate when the list length is increased from four to five items than when the list is increased from three to four items. This interpretation of the P x L

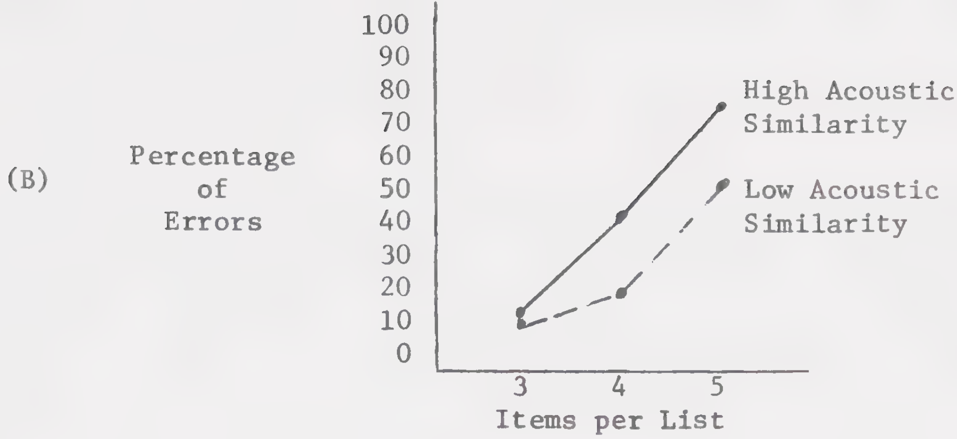
interaction may, however, be biased by the floor and ceiling effects.

The first order interactions which were not significant were G x A, G x P, and A x P. These results would indicate that Grades Three and Five did not differ in the degree of error increases at either acoustic similarity level (17% error difference between Grades Three and Five at the low acoustic similarity condition versus 18% error difference on the high acoustic similarity condition). The percentage of errors made by Grade Three on the low acoustic condition is, however, equal to the number of errors made by the Grade Five subjects on the high acoustic condition (44% versus 44%).

The nonsignificant G x L interaction indicates that the differences observed between the grades at each of the three list lengths did not differ from each other (15% versus 20% versus 18%). Similarly, the lack of an A x P interaction indicates that the differences between the two acoustic conditions at each of the presentation rates did not differ from each other (17% versus 19% versus 15%).

Second Order Interactions

The L x G x A interaction was significant ($p<.01$). A Scheffée comparison was run on the means and the following results were obtained. The differences between the high and low acoustic similarity conditions were not significant when the list contained only three items for either grade. The differences between the high and low acoustic similarity conditions were significant for the four and five item lists for both grades. The pattern of errors was very similar



GRADE FIVE

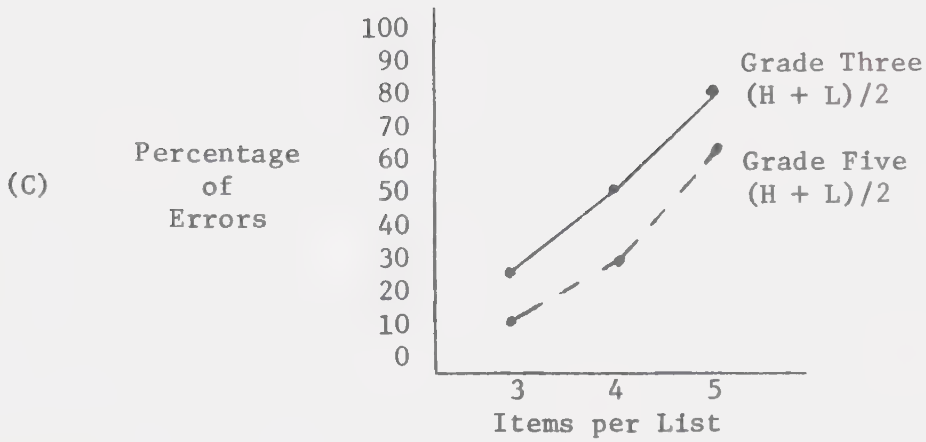


FIGURE 10

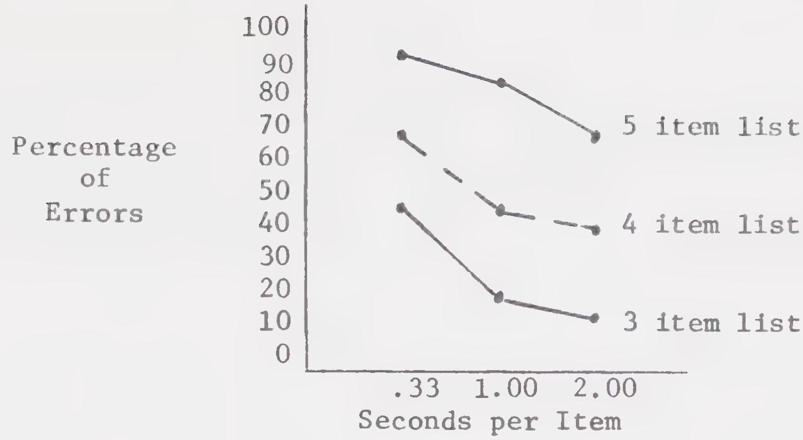
LIST LENGTH BY GRADE BY ACOUSTIC SIMILARITY INTERACTION

between grades as is clearly shown by the graphs in Figure 10. The interaction appears to be caused by an overall error increase for the Grade Three subjects and by an increase in errors being observed between the acoustic variables when the list is four or five items long, but not with the three item list. This interaction is subject to the same qualifications applying to the A x L interaction discussed earlier.

The G x L x P interaction was significant ($p<.01$) and is presented graphically in Figure 11. Differences within each grade level with regard to presentation rate clearly exist. With Grade Three (Figure 11A), the increase in errors obtained by increasing the list length from four to five items was significantly greater than the increase in errors obtained by increasing the list from three to four items at the 1.00 second rate. A significant increase in errors was caused when the rate was increased from 1.00 seconds to .33 seconds per item for a three or four item list, but not when the list contained five items. There was a significant increase in errors when the presentation rate was increased from 2.00 to 1.00 seconds per item when the list contained five items, but not when the list contained three or four items.

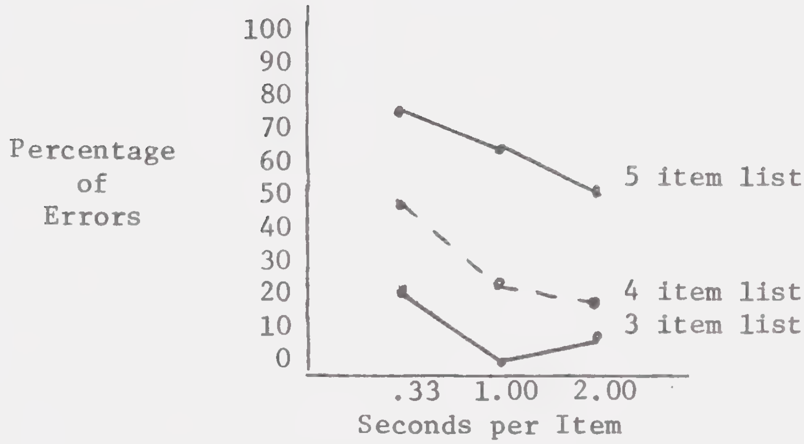
For Grade Five (Figure 11B), a significant increase in errors was observed when the list length was increased for any presentation rate except when the list was increased from three to four items at the 2.00 second presentation rate. A similar finding was observed for the Grade Five subjects as for the Grade Three subjects in that no significant differences were noted as the presentation rate was decreased from

(A)



GRADE THREE

(B)



GRADE FIVE

(C)

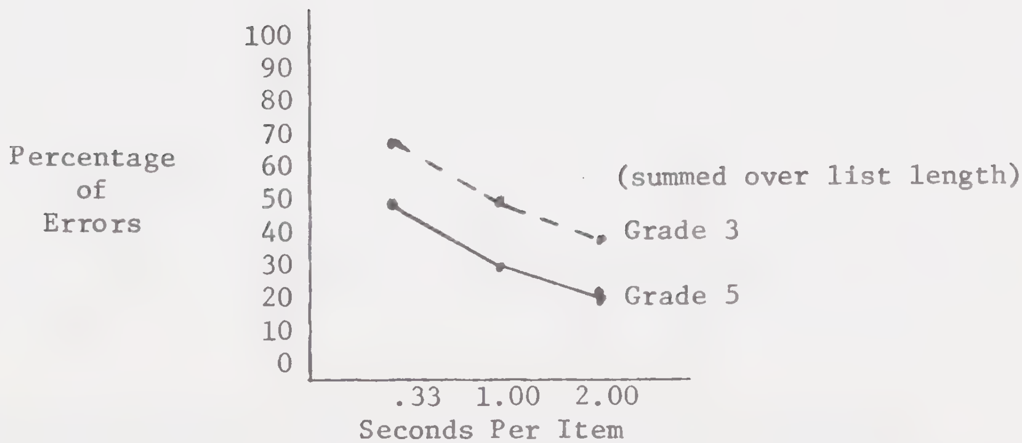


FIGURE 11

GRADE BY LIST LENGTH BY PRESENTATION RATE
INTERACTION

.33 seconds to 1.00 seconds for a five item list and that no differences were found when the presentation rate was decreased from 1.00 to 2.00 seconds for the three and four item lists. The interaction appears to be caused by the differences between the grades when the list is increased from three to four items at a 2.00 second presentation rate. The final interpretation of this interaction should take into account the scaling effects which were discussed earlier.

The A x L x P interaction was significant ($p<.01$). Figure 12 graphically displays this interaction. Figure 12A indicates that as the list length is increased at any of the three presentation rates, the number of errors increased significantly when high acoustically similar stimuli are used. As the presentation rate increases for each list length, significant differences occur for each individual list length except when the presentation rate is decreased from 1.00 to 2.00 seconds per item on the three item list and from .33 seconds to 1.00 seconds on the five item list. The increase in the number of errors observed when the list was increased from three to four items was greater than when the list length was increased from four to five items at the .33 second presentation rate. The opposite finding was true for the 2.00 second presentation rate (i.e., the increase from four to five items was larger than the increase from three to four items.

Figure 12B indicates that by increasing the list length at a given presentation rate with stimuli of low acoustic similarity produces

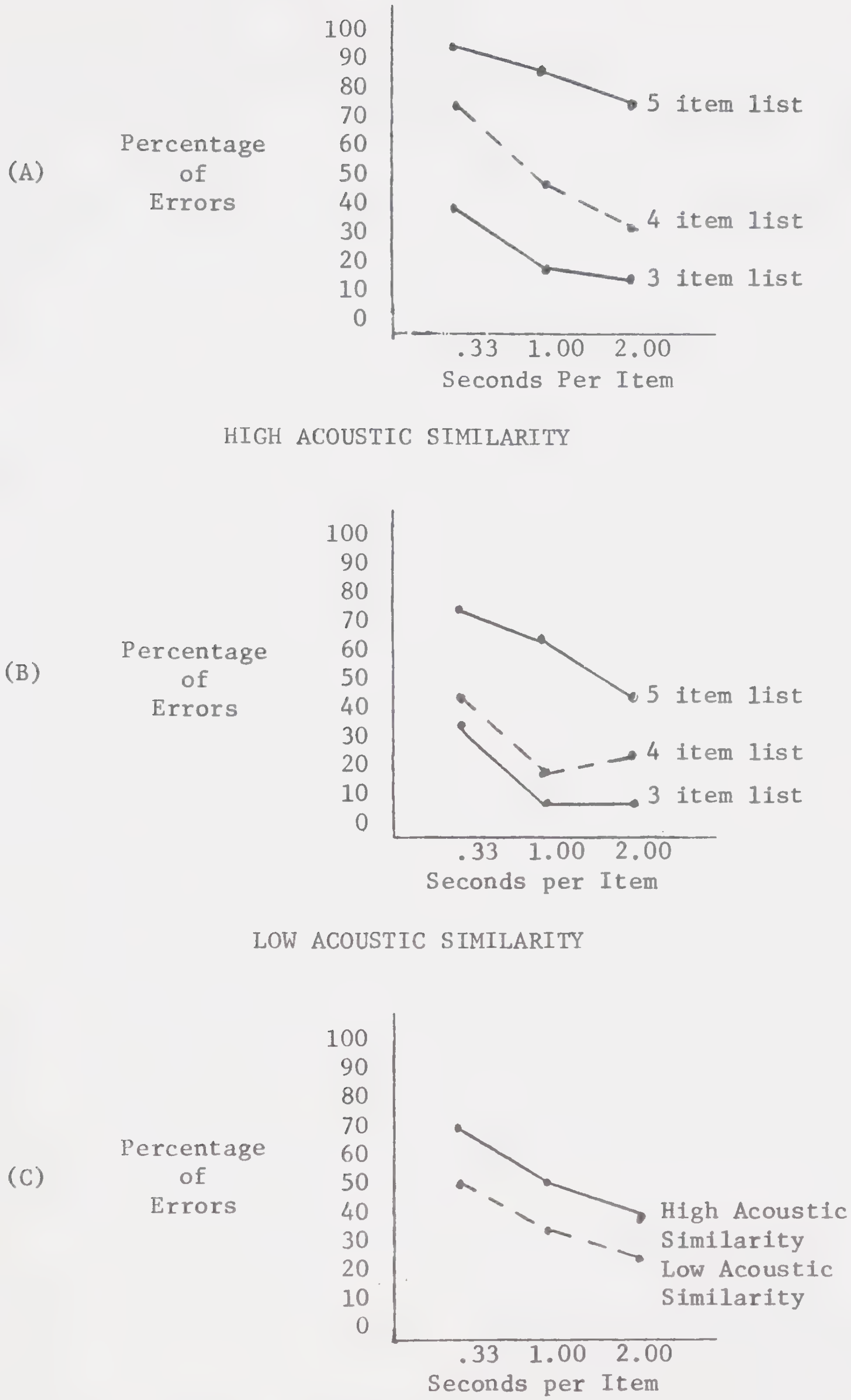


FIGURE 12

ACOUSTIC SIMILARITY BY LIST LENGTH BY PRESENTATION RATE INTERACTION

significant differences except when the list length was increased from three to four items at the .33 second presentation rate. Significant error increases were also observed when the presentation rate was increased from 1.00 to .33 seconds for the three and four item lists and from 2.00 to 1.00 seconds for the five item list. The increase in the observed number of errors obtained resulting from an increase in list length from four to five items was significantly greater than when the list length was increased from three to four items for the .33 and 1.00 second presentation rates. Overall, the high acoustic similarity caused a greater number of errors to be observed on the four and five item lists but not on the three item lists. The increase in number of errors obtained when the list length is increased from three to four on the .33 and 1.00 second presentation rates is significantly greater on the high acoustic similarity condition than on the low. Similarly, the increase in errors obtained by increasing the list length from four to five items is greater on the high acoustic similarity than the low when the 2.00 second presentation rate is used. Generally, the results indicate that high acoustic similarity causes a greater number of recall errors than low acoustic similarity when list length and presentation rate are varied.

The G x A x P interaction was not significant. Thus, the differences in percentage of errors obtained between the acoustic levels at each presentation rate did not differ signficantly between grades. As with all previous significant interactions, the possibility exists that the results are an artifact of scaling effects and in violation of the homogeneity of error variance assumption of the analysis of

variance model. A discussion of the interaction results with regard to their biases is contained in Chapter VI.

Third Order Interactions

The third order interaction, Grade Level by Acoustic Similarity by List Length by Presentation Rate was not significant.

Summary of Results

The results indicate that all main effects were significant. The Grade Five subjects performed at a higher level than the Grade Three subjects. Stimuli which were acoustically similar caused a greater number of recall errors than acoustically dissimilar stimuli The five item list produced the greatest number of recall errors and the slowest rate (2.00 seconds per item) produced the least. Possible factors evident in the results which might influence the significance of the interactions effects were then discussed. An A x L interaction was significant where the difference between the high and low acoustic similarity conditions when the five item list was used was greater than the difference obtained between the high and low acoustic similarity conditions when the three item list was used. The L x P interaction indicated that the List Length and Presentation Rate main effects were non-additive because the differences obtained between the different list lengths at any given presentation rate were not necessarily the same. The G x A x L interaction indicates that the Grade Five subjects generally differed from the Grade Three subjects in the amount of errors made at the different levels of acoustic similarity at each of the three list lengths.

The G x L x P interaction indicates that the Grade Three subjects and the Grade Five subjects differed in their abilities to handle different list lengths at different presentation rates. The A x L x P interaction showed that, at each level of acoustic similarity, the subjects differed in their ability to correctly recall different length lists at different presentation rates. The following chapter offers a discussion of these results in relation to the hypotheses presented in Chapter III.

CHAPTER VI

DISCUSSION

The obtained results follow closely to those hypothesized. This chapter discusses the results in relation to the hypotheses. A discussion on the results which involve grade differences is then presented followed by a discussion of how the scaling bias may affect the results. A summary of the results and possible educational relevance are then discussed in Chapter VII.

Hypothesized Results Versus Experimental Results

Hypothesis One predicted a greater number of errors would be obtained for both grades on the high acoustic similarity condition than on the low acoustic condition. This was substantiated by the significant acoustic main effect. Acoustic interference is prominent in the learning processes of children, indicated by the high percentage of errors obtained on the high acoustic similarity condition. This interference pattern is, then, not unique to adults.

The second hypothesis predicted an increase in observed recall errors as the list length increased from three to five items. The results clearly indicate that the greatest number of errors were observed on the five item lists, the second most on the four item lists, and the least number were observed on the three item lists. By increasing the number of items to be learned within a list from three to four items or from four to five items, the chances of a subject making an error increases from 17% to 40% to 73%, respectively. Indications are that learning efficiency greatly decreases when five items or more

are incorporated into a list. The results also indicate that the short-term memory span of children of Grade Five is greater than the Grade Three subjects.

The third hypothesis predicted an increasing number of observed errors as the presentation rate increased. This was shown to be true The chances of a subject making an error when the presentation rate was 2.00 seconds per item was 33%. At 1.00 seconds per item, the chances increased to 40% and, from there, to 57% at the .33 seconds per item rate. Increasing the presentation rate from 2.00 to 1.00 seconds per item increases the degree of difficulty by 7%, whereas, increasing the presentation rate from 1.00 seconds per item to .33 seconds per item, increases the difficulty by 17%. The study time allowed by the presentation rate affects learning by controlling rehearsal time.

Hypothesis Four predicted a List Length by Presentation Rate interaction and was supported by the experimental findings. With a three item list length, the fewest errors were observed at the 2.00 second presentation rate. However, as the list length increased to four items and five items, the difficulty of recall also increased. No differences were observed between the 1.00 and 2.00 second rates. for a list length of three items. For four items the difference is 5%, and for five items the difference is 17%. The effect of increasing the list length and increasing the presentation rate from 1.00 seconds to .33 seconds per item is the reverse. For the three item list, the change was 22%, for the four item list, the change was 24%, and for the five item list the change was 6%. There appears

to be a pattern between the items to be learned and the amount of time required to rehearse these items between successive stimuli presentations such that they can be stored in a manner suitable for recall. Since the three item list produced no change in learning (between the 1.00 and 2.00 second rate), it is assumed that the subjects had adequate learning time at the 1.00 second rate and gained little by having the time increased to two seconds. With four items, however, the subject's error rate increased to 33% at the 1.00 second rate and decreased only 5% when the presentation rate was decreased to 2.00 seconds per item. If the rehearsal function were linear and the list length was only increased by 1/3, then only 1/3 more rehearsal time should be required. This does not appear to be the case. The subject's performance appears to be a nonlinear function of the list length, presentation rate, and the amount of interference encountered during stimulus coding. The result of removing one source of interference (acoustic similarity) is discussed later in this chapter.

The fifth hypothesis predicted an Acoustic Similarity by List Length interaction. This interaction was observed to be significant. The differences between the high and low acoustic similarity conditions were significant when the list length was four or five items, but not when the list contained three items. The amount of interference generated by acoustic similarity is not sufficient to cause the subject significant learning difficulties when the list is short (in this case, three items long). As the list length increases, the degree of interference greatly increases, causing the subject recall difficulties. Subject errors on the high acoustic similarity conditions increase from

20% for a three item list to 52% for a four item list and, then, to 84% for a five item list. The control (non-acoustically similar) condition produced 15%, 27%, and 62% errors on the three, four, and five item lists. By having the stimuli acoustically similar, the number of errors increased 25% and 22% on the four and five item lists. These results indicate that children are subject to errors similar to adults.

A significant Acoustic Similarity by List Length by Presentation Rate interaction was predicted by Hypothesis Six. This interaction was significant and indicates that the subjects are affected by the interference brought about by the introduction of acoustic similarity. By increasing the list length from three to four items with a high similarity list, errors were increased 43% when the presentation rate was .33 seconds per item, 34% when the presentation rate was 1.00 seconds per item, and 22% when the presentation rate was 2.00 seconds per item. The Control group increases are 10%, 13%, and 16%, respectively. Clearly, acoustic similarity produces a greater number of recall errors on the .33 and 1.00 second presentation rates than on the 2.00 second presentation rate. With the 2.00 second presentation rate, the experimental and control conditions differ only by 6% in the errors caused by increasing the list length from three to four items. What appears to be happening is that subjects are better able to handle the interference caused by increasing the list length if a longer presentation rate is used. Presumeably, the subject uses this added time to rehearse the stimulus list. Large increases in percentage errors were observed on the low similarity list when the list was increased from four to five items at all three presentation rates (33%, 48%, 24%). This large

increase signifies that the subject has extended the limits within which he can comfortably and adequately handle the interference caused by list length at that particular presentation time. When the subject has the added difficulty of increased acoustic similarity on the five item list, he makes 92% errors at the .33 second presentation rate, 87% at the 1.00 second rate, and 74% at the 2.00 second rate as compared to the low similarity list errors of 74%, 67%, 46%. Basically, the subjects appear able to adequately handle stimuli lists of three or four items which are not acoustically similar, but have greater difficulty if acoustic similarity is introduced into the list structure. Further, if the presentation time is not increased to an extent such that the subject is able to cope with the interfering effects of acoustically similar stimuli, errors will increase substantially.

Hypothesis Seven predicted that, summed over all conditions, grade five subjects would make fewer recall errors than the grade three subjects. This is apparent throughout the data and is verified by the significant grade level effect. Higher familiarity with the stimulus material, greater exposure to interference, and the experience of handling learning material which is complex may be some of the factors underlying the superior performance of the Grade Five subjects over the Grade Three subjects. However, Grade Five subjects are still vulnerable to interference, as indicated by the significant acoustic similarity results.

Unpredicted Results

The hypotheses were based on the anticipation of the results of adults in similar conditions and, consequently, no prediction could be made on the possible differences which might occur between grade levels. As the results followed exceedingly closely to the predicted results, there is no evidence to suggest that children's short-term memory processes are qualitatively different than that of adult subjects. There were some grade differences observed in the experimental results, through. The Grade main effect was significant, indicating that the Grade Five subjects made fewer errors that grade three subjects. The more efficient learning of Grade Five subjects is probably due to a greater ability to break down interference patterns caused by properties within the stimulus list. One form of interference introduced into the learning task was acoustic similarity. The Grade by Acoustic Similarity interaction was not significant, indicating the degree of error increases at either acoustic similarity did not differ between grades (17% versus 18%). A Newman-Keuls comparison of the means indicated that the Grade Three subjects made a larger, significant number of errors on the high similarity list (61% versus 44%) and on the low similarity list (44% versus 26%) than did the Grade Five subjects. It seems likely that the Grade Five and Grade Three subjects are overcoming the acoustic interference in similar ways, but that the Grade Five subjects are more proficient in this task. This finding was consistent in the other first order interactions involving a grade variable (G x L, G x P).

Two second order interactions (G x A x L and G x L x P) were significant. Analysis of the Grade by Acoustic Similarity by List Length interaction indicated that the Grade Five subjects performed the recall task with fewer errors than the Grade Three subjects on each list length at each presentation rate. The interaction effect is also due to a non-significant difference between the high and low similarity list conditions when the list contains three items. As the list length is increased to four or five items, the differences between the high and low similarity groups becomes significant for both grades. The difference in recall errors caused by a list similarity increase was roughly the same for each grade for each list length (26% versus 23% and 16% versus 28%). Once again, the evidence indicates that the acoustic similarity causes the same degree of interference in both groups but that list length presents less difficulty to the Grade Five subjects.

The significant Grade by List Length by Presentation Rate interaction indicated that the Grade Five subjects made fewer errors as the presentation rate and list length decreased. The effect of the list length increase from three to four items for the 2.00 second presentation rate was not as great for the Grade Five subjects as it was for the Grade Three subjects. The 2.00 second presentation rate was not sufficient for the Grade Three subjects to overcome the list length interference while it was sufficient for the Grade Five subjects. The five item list is beyond the capacity of a Grade Three student, causing a high percentage of recall errors (92% to 69%, depending on the presentation rate). For Grade Five subjects, recall errors are

also high. However, they are still less than those obtained by the Grade Three subjects (75% to 51%, depending on the presentation rate).

In summary, for Grade Three, learning is most efficient when the list is not over three items long, is presented no faster than 1.00 seconds per item, and contains no acoustic interference. For the Grade Five subjects, the list may be up to four items long when presented at a 2.00 seconds per item rate, and may contain acoustic interference if the list length is below four items. Shorter list lengths may be presented at a faster presentation rate, but must then contain no acoustic interference. Or, in other words, added acoustic interference must be compensated for by decreasing the rate of presentation.

Ceiling and Floor Effects

The results of the analyses presented in this paper may have been affected by a scaling factor that would artificially create significant interactions due to floor or ceiling effects. In varying degrees, all significant interactions in the present study demonstrate this effect. The floor effect, in these data the fewest number of errors, appears to reach its lower asymptote around the 10% error level. With 78 subjects encompassing the entire range of students included in each grade level, it is not unlikely that six or seven subjects per grade would make an error on even the simplest condition (low similarity items presented at a 2.00 second presentation rate). This would account for why the floor effect is at the 10% level and

not at the 0% level. The lower asymptote was reached on the basis that subjects found the task under the simplest conditions to be well within their learning capabilities. As the subjects encountered lists which exceeded their capacity, they reached the upper asymptote of 100% errors. If subjects were selected so as to eliminate the poorer subjects as well as the very bright, perhaps these effects could be lessened. This study was, however, designed to investigate the existence of acoustic interference in children as a group and not on an individual basis. The heterogeneity of variance does suggest that differences may occur. How greatly these biases affect the results is difficult to assess.

CHAPTER VII

SUMMARY

A review of the literature of variables in short-term memory failed to reveal any study which provided evidence of acoustic interference in children. The experimental factors affecting the observation of acoustic interference in adults were then summarized. The results of this summary provided the basis for a 2 x 2 x 3 x 3 factorial, repeated measures experiment designed to determine if acoustic interference was present in children's learning behavior. The four experimental factors (Grade Level, Acoustic Similarity, List Length, and Presentation Rate) were selected as having the greatest significance in an acoustic interference study.

A serial list, short-term memory task, based on Conrad's early experiments in studying acoustic interference, was selected as the experimental task. The stimulus lists were selected at random from a set of acoustically similar letters or a set of acoustically dissimilar letters. The lists contained 3, 4, or 5 items which were sequentially presented at .33, 1.00, or 2.00 seconds per item to subjects selected from Grades Three and Five. Seventy-eight subjects per grade contributed to the experimental analysis.

The stimuli were presented to a whole class of subjects simultaneously by means of a seventeen minute, sixteen millimeter film containing 68 trials. Following the presentation of a list of stimuli, the subjects immediately recalled the stimuli, in serial order, in an answer booklet during an eleven second recall period. Only one list was recalled on each answer booklet page. The subjects

were promised a prize, consisting of a chocolate bar, for doing a good job. Each participating child received this prize.

The results indicated that all four experimental variables significantly affected the subject's learning behavior. The Grade Three subjects made a greater number of errors than did the Grade Five subjects. As the list length increased from three to five items, the subjects in both grades tended to make a greater number of errors. The subjects also increased the number of recall errors made when the presentation rate increased from .33 seconds to 2.00 seconds per item. And lastly, subjects made a greater number of recall erros on the acoustically similar list than they did on the acoustically dissimilar lists. A number of significant interactions were also found.

Educational Relevance

The results indicate that organization and presentation of a stimulus list is very important. Learning material containing a large number of stimuli which are acoustically similar would tend to cause the pupils more difficulty than if the material were organized to contain little acoustic similarity. The organization of spelling lists would be one example where such information would be useful, but would apply to most rote memory situations.

Conclusion

The purpose of this research was to consolidate the variables, in short-term memoy in adults, which pertain to acoustic interference, and then to determine if acoustic interference existed in

children. The data herein reported indicated that children were subject to acoustic interference under conditions similar to those found for adults and, thus, acoustic variables should be controlled in the learning situations to which the child is exposed.

REFERENCES

Adams, J. A. Human memory. New York: McGraw-Hill, 1967.

Adams, J. A., Thorsheim, H. I., and McIntyre, J. S. Item length, acoustic similarity, and natural language mediation as variables in short-term memory. Journal of Experimental Psychology, 1969, 80, 1, 39-46.

Adams, J. A., Thorsheim, H. I., and McIntyre, J. S. Short-term memory and acoustic similarity. Psychonomic Science, 1969, 15, 77-78.

Atkinson, R. C. and Shiffrin, R. M. Human memory: a proposed system and its control process. In K. W. Spence and J. T. Spence (eds.), The psychology of learning and motivation, Volume 2, New York: Academic Press, 1968.

Baddeley, A. D. Semantic and acoustic similarity in short-term memory. Nature, 1964, 204, 1116-1117.

Baddeley, A. D. Short-term memory for word sequences as a function of acoustic, semantic, and formal similarity. Quarterly Journal of Experimental Psychology, 1966, 18, 362-365.

Baddeley, A. D. and Dale, H. C. A. The effect of semantic similarity on retroactive interference in long- and short-term memory. Journal of Verbal Learning and Verbal Behavior, 1966, 5, 417-420.

Bruce, D. and Murdock, B. B. Acoustic similarity effects of memory for paired associates. Journal of Verbal Learning and Verbal Behavior, 1965, 4, 161-169.

Conrad, R. An association between memory errors and errors due to acoustic masking of speech. Nature, 1962, 193, 1314-1315.

Conrad, R. Acoustic confusions and memory spans for words. Nature, 1963, 197, 1029-1030.

Conrad, R. Acoustic confusions in immediate memory. British Journal of Psychology, 1964, 53, 75-84.

Conrad, R. Overt errors in immediate recall of sequences. Journal of Verbal Learning and Verbal Behavior, 1965, 4, 161-169.

Conrad, R. Interference or decay over short retention intervals? Journal of Verbal Learning and Verbal Behavior, 1967, 6, 49-64.

Conrad, R., Baddeley, A. D., and Hull, A. J. Rate of presentation and the acoustic similarity effect in short-term memory. Psychonomic Science, 1966, 5, 233-244.

Conrad, R., Freeman, P. R., and Hull, A. J. Acoustic factors versus language factors in short-term memory. Psychonomic Science, 1965, 3, 57-58.

Conrad, R., and Hull, A. J. Information, acoustic confusion, and memory span. British Journal of Psychology, 1969, 55, 429-432.

Conrad, R. and Rush, M. L. On the nature of STM encoding by the deaf. Journal of Speech and Hearing Disorders, 1965, 30, 336-343.

Dale, H. C. A. and Gregory, M. Evidence of semantic coding in short-term memory. Psychonomic Science, 1966, 5, 75-76.

Ebbinghaus, H. Memory: a contribution to experimental psychology. Translated by H. A. Ruger and C. E. Bussenius. New York: Teachers College, Columbia University Press, 1913.

Henley, N. M., Noyes, H. L., and Deese, J. Semantic structure in short-term memory. Journal of Experimental Psychology, 1968, 77, 587-592.

Hintzman, D. Classification and aural coding in short-term memory. Psychonomic Science, 1965, 3, 161-162.

Kintsch, W. and Buschke, H. Homophones and synonyms in short-term memory. Journal of Experimental Psychology, 1969, 80, 403-407.

Kirk, R. E. Experimental design: procedures for the behavioral sciences. Belmont, California: Brooks Cole Publishing Company, 1968.

Laughery, K. R. and Pinkus, A. L. STM: effects of acoustic similarity, presentation rate, and presentation mode. Psychonomic Science, 1966, 6, 285-286.

Melton, A. W. Implications of short-term memory for a general theory of memory. Journal of Verbal Learning and Verbal Behavior, 1963, 2, 1-21.

Miller, G. A. The magical number seven plus or minus two: some limits on our capacity for processing information. Psychological Review, 1956, 63, 81-87.

Milner, B. The memory defect in bilateral hippocampol lesions. Psychiatric Research Reports, 1959, 11, 43-58.

Milner, B. Neuropsychological evidence for differing memory processes. Abstract for the symposium on short-term and long-term memory. Proceedings of the 18th International Congress of Psychology, Moscow, 1968.

Postman, L. Short-term memory and incidental learning. In A. W. Melton (ed.), Categories of human learning. New York: Academic Press, 1964, pp. 145-205.

Reicher, G. M., Ligon, E. J., and Conrad, C. M. Interference in short-term memory. Journal of Experimental Psychology, 1969, 80, 95-100.

Sperling, G. The information available in brief visual presentations. Psychology Monographs, 1960, 74

Sperling, G. A model of visual memory tasks. Human Factors, 1963, 19-31.

Sperling, G. Successive approximating to a model for short-term memory. Acta Psychologica, 1967, 27, 285-292.

Sperling, G. and Speelman, R. G. In Norman, D. A. (ed.), Models of human memory. New York: Academic Press, 1970.

Wickelgren, W. A. Acoustic similarity and intrusion errors in short-term memory. Journal of Experimental Psychology, 1965, 70 102-108.

Wickelgren, W. A. Acoustic similarity and retroactive interference in short-term memory. Journal of Verbal Learning and Verbal Behavior, 1965, 5, 53-61.

Wickelgren, W. A. Short-term memory and interference in short-term recall for single letters. Journal of Experimental Psychology, 1966, 71, 396-404.

Wickelgren, W. A. Short-term memory for single letters and phonemic similarity of retroactive inhibition. Quarterly Journal of Experimental Psychology, 1966, 18, 55-62.

Wickens, D. D. and Eckler, G. R. Semantic as opposed to acoustic coding in short-term memory. Psychonomic Science, 1968, 12, 63.

APPENDIX A

PRODUCTION OF FILM

Appendix A contains a description of the manufacturing process by which the film which was used to present the stimulus lists was produced.

The stimulus letters were typed on 3 x 5 inch index cards which were the placed in the order necessary to make up the appropriate lists. The cards were photographed using a 16-mm Bolex H-16 movie camera on Kodak Tri-X reversal film. The 16-mm film projector ran at a constant speed of 24 frames per second. Hence, a stimulus which was presented for .33 seconds was photographed for eight frames, for 1.00 second for 24 frames and for 2.00 seconds for 48 frames. Following film development, 192 frames of green leader followed by 72 frames of red leader were spliced on the last frame of the last stimulus of each list. The last frame of red leader was then spliced to the first frame of the first stimulus of the next list. The process was repeated for 68 trials and for four practice trials.

This method of stimulus presentation to a large group of subjects proved to be very feasible. The film was inexpensive when compared to the building of elaborate presentation and timing equipment. The film eliminated the need to use electronic timers to control presentation rate, allowed for various presentation rates which could be accurately controlled, used equipment which was easily accessible, and was relatively simple and quick to make. Not only were a large number of subjects able to be run at one time, but the equipment was portable and caused no disturbances among the subjects as being unfamiliar to them. The method was also widely accepted by the school

board. The advantages of using a film for stimulus presentation greatly facilitated the collection of data for this thesis research.

APPENDIX

RAW DATA SUMMARY

This appendix contains a summary of the raw data for each grade. Each summary sheet contains four error matrices. The two on the left give the total errors made for that grade on each list length for each presentation rate for each acoustic similarity condition. The two on the right contain the transformation of the number of errors observed in the left hand matrices to percentage of errors for each presentation rate at each list length for each of the two similarity condition. The percentage of error matrices facilitate comparison of different grade results. Also included in this appendix is a summary of each of the overall grade results for each grade and a summary of the combined results for both grades. A table containing the means and variances for each experimental condition of the data used is presented at the end of Appendix C.

ACOUSTIC SIMILARITY

LOW

NUMBER OF ERRORS

LIST LENGTH	PRESENTATION RATE .33	1.0	2.0	
3	24	12	7	43
4	51	38	28	117
5	66	65	60	191
	141	115	95	351

PERCENTAGE OF ERRORS

LIST LENGTH	PRESENTATION RATE .33	1.0	2.0	
3	35	17	10	21
4	74	55	41	77
5	96	56	46	92
	68	56	46	57

HIGH

NUMBER OF ERRORS

LIST LENGTH	PRESENTATION RATE .33	1.0	2.0	
3	28	3	9	40
4	35	15	23	73
5	51	51	43	145
	114	69	75	258

PERCENTAGE OF ERRORS

LIST LENGTH	PRESENTATION RATE .33	1.0	2.0	
3	41	4	13	19
4	51	22	33	35
5	74	74	62	70
	55	33	36	42

GRADE 3-1

n=23

ACOUSTIC SIMILARITY

LOW

PRESENTATION RATE

.33	1.0	2.0	
30	15	9	54
44	35	18	97
50	44	34	128
124	94	61	279

PRESENTATION RATE

.33	1.0	2.0		LIST LENGTH
59	29	18	36	3
86	67	35	64	4
98	86	67	84	5
81	62	40	61	

HIGH

.33	1.0	2.0	
19	6	2	27
30	12	15	57
48	37	22	107
97	55	39	191

NUMBER OF ERRORS

.33	1.0	2.0		LIST LENGTH
37	12	4	18	3
59	24	30	38	4
95	73	44	70	5
64	36	26	42	

PERCENTAGE OF ERRORS

GRADE 3-2

n=17

ACOUSTIC SIMILARITY

PRESENTATION RATE

LOW	.33	1.0	2.0	
	31	13	9	53
	56	36	30	122
	63	60	45	168
	150	109	84	343

PRESENTATION RATE

.33	1.0	2.0		LIST LENGTH
47	20	4	27	3
85	55	46	62	4
96	91	69	85	5
76	55	43	58	

HIGH	.33	1.0	2.0	
	25	13	8	46
	35	21	23	79
	63	57	38	158
	123	91	69	283

NUMBER OF ERRORS

.33	1.0	2.0		LIST LENGTH
38	20	13	24	3
53	32	35	40	4
96	87	58	80	5
63	46	35	48	

PERCENTAGE OF ERRORS

GRADE 3-3

n=22

ACOUSTIC SIMILARITY

LOW — PRESENTATION RATE (NUMBER OF ERRORS)

.33	1.0	2.0	
24	16	8	48
43	32	29	104
47	48	47	142
114	96	84	294

LOW — PRESENTATION RATE (PERCENTAGE OF ERRORS)

.33	1.0	2.0		LIST LENGTH
50	34	17	33	3
90	67	61	72	4
98	100	98	99	5
79	67	58	68	

HIGH — NUMBER OF ERRORS

.33	1.0	2.0	
24	2	4	30
19	12	17	48
40	42	30	112
83	56	51	190

HIGH — PERCENTAGE OF ERRORS

.33	1.0	2.0		LIST LENGTH
50	4	8	21	3
40	25	35	33	4
83	88	63	78	5
58	39	35	44	

NUMBER OF ERRORS

PERCENTAGE OF ERRORS

GRADE 3-4

n=16

ACOUSTIC SIMILARITY

LOW

NUMBER OF ERRORS

PRESENTATION RATE	.33	1.0	2.0	
	109	56	33	198
	194	141	105	440
	226	217	186	629
	529	414	324	1267

PERCENTAGE OF ERRORS

PRESENTATION RATE	.33	1.0	2.0		LIST LENGTH
	47	24	14	28	3
	83	60	45	63	4
	97	93	79	90	5
	75	59	46	90	

HIGH

NUMBER OF ERRORS

PRESENTATION RATE	.33	1.0	2.0	
	96	24	23	143
	119	60	78	257
	202	187	133	522
	417	271	234	922

PERCENTAGE OF ERRORS

PRESENTATION RATE	.33	1.0	2.0		LIST LENGTH
	41	10	6	20	3
	35	26	33	37	4
	86	80	57	74	5
	59	39	33	44	

TOTAL FOR GRADE 3

n=78

ACOUSTIC SIMILARITY	LIST LENGTH	NUMBER OF ERRORS: PRESENTATION RATE .33	1.0	2.0		PERCENTAGE OF ERRORS: PRESENTATION RATE .33	1.0	2.0	
LOW	3	16	4	7	27	18	5	8	10
LOW	4	64	29	17	110	74	33	20	42
LOW	5	78	73	57	208	90	84	66	80
LOW		138	106	81	345	61	41	31	44
HIGH	3	21	3	0	24	24	3	0	9
HIGH	4	27	11	8	46	31	13	9	18
HIGH	5	58	48	28	134	67	55	32	51
HIGH		106	62	28	204	67	55	32	51

GRADE 5-1

n=29

ACOUSTIC SIMILARITY

LOW

PRESENTATION RATE

.33	1.0	2.0	
21	2	10	33
54	28	23	105
71	63	64	198
146	93	97	336

PRESENTATION RATE

.33	1.0	2.0		LIST LENGTH
24	2	11	13	3
62	32	26	40	4
82	72	74	76	5
56	36	37	43	

HIGH

.33	1.0	2.0	
21	1	2	24
26	9	9	44
54	46	33	133
101	56	44	201

NUMBER OF ERRORS

.33	1.0	2.0		LIST LENGTH
24	1	2	69	3
30	10	10	17	4
62	53	38	51	5
39	21	17	26	

PERCENTAGE OF ERRORS

GRADE 5-2

n=29

ACOUSTIC SIMILARITY

LOW

PRESENTATION RATE

List length	.33	1.0	2.0	
3	8	4	5	17
4	34	28	15	77
5	56	52	45	153
	98	84	65	247

PRESENTATION RATE

.33	1.0	2.0		LIST LENGTH
13	7	8	9	3
57	47	25	43	4
93	87	75	85	5
54	47	36	46	

HIGH

List length	.33	1.0	2.0	
3	8	0	4	12
4	19	8	7	34
5	35	31	22	88
	62	39	33	134

.33	1.0	2.0		LIST LENGTH
13	0	7	7	3
32	13	12	19	4
58	52	37	49	5
34	22	18	25	

NUMBER OF ERRORS (left tables)

PERCENTAGE OF ERRORS (right tables)

GRADE 5-3

n=20

ACOUSTIC SIMILARITY

PRESENTATION RATE

LOW	.33	1.0	2.0	
	15	4	6	25
	42	33	16	91
	66	55	47	168
	123	92	69	284

PRESENTATION RATE

.33	1.0	2.0		LIST LENGTH
22	6	9	12	3
61	48	23	44	4
96	80	63	81	5
59	44	33	46	

HIGH	.33	1.0	2.0	
	12	1	2	15
	10	11	5	26
	42	26	23	91
	64	38	30	132

NUMBER OF ERRORS

.33	1.0	2.0		LIST LENGTH
17	1	3	7	3
14	16	7	13	4
61	38	33	44	5
31	18	14	21	

PERCENTAGE OF ERRORS

GRADE 5-4

n=23

ACOUSTIC SIMILARITY

LOW — NUMBER OF ERRORS

List length	.33	1.0	2.0	Total
3	60	14	28	102
4	194	118	71	383
5	271	247	213	731
Total	525	379	312	1216

LOW — PERCENTAGE OF ERRORS

List length	.33	1.0	2.0	Total
3	20	5	9	11
4	64	39	23	42
5	89	82	70	80
Total	58	42	34	45

HIGH — NUMBER OF ERRORS

List length	.33	1.0	2.0	Total
3	62	5	8	75
4	82	39	29	150
5	189	151	106	446
Total	333	195	106	671

HIGH — PERCENTAGE OF ERRORS

List length	.33	1.0	2.0	Total
3	20	2	3	8
4	27	13	10	17
5	62	50	70	49
Total	37	21	16	25

PRESENTATION RATE

LIST LENGTH

NUMBER OF ERRORS

PERCENTAGE OF ERRORS

TOTAL FOR GRADE FIVE

n=78

ACOUSTIC SIMILARITY

NUMBER OF ERRORS

PRESENTATION RATE

LOW

.33	1.0	2.0	
169	70	61	300
388	259	176	823
497	464	399	1360
1054	793	636	2483

HIGH

.33	1.0	2.0	
158	29	31	218
201	99	107	407
391	383	239	968
750	466	377	1593

PERCENTAGE OF ERRORS

PRESENTATION RATE

LOW

.33	1.0	2.0		LIST LENGTH
31	13	11	19	3
72	48	33	51	4
93	86	74	84	5
65	49	39	51	

HIGH

.33	1.0	2.0		LIST LENGTH
29	5	6	14	3
37	18	20	25	4
73	71	45	60	5
47	29	23	33	

TOTAL FOR GRADES 3 AND 5 COMBINED

n=156

ACOUSTIC SIMILARITY	LIST LENGTH (Items per List)	PRESENTATION RATE (Items per Second)			PRESENTATION RATE (Items per Second)		
		.33	1.00	2.00	.33	1.00	2.00
HIGH	3	$\bar{X}$ =1.95 S^2= .80	$\bar{X}$ = .72 S^2= .61	$\bar{X}$ = .47 S^2= .48	$\bar{X}$ = .56 S^2= .53	$\bar{X}$ = .14 S^2= .15	$\bar{X}$ = .31 S^2= .32
	4	$\bar{X}$ =2.49 S^2= .45	$\bar{X}$ =1.81 S^2= .82	$\bar{X}$ =1.37 S^2=1.05	$\bar{X}$ =1.95 S^2= .89	$\bar{X}$ =1.06 S^2= .85	$\bar{X}$ = .71 S^2= .52
	5	$\bar{X}$ =2.90 S^2= .09	$\bar{X}$ =2.78 S^2= .38	$\bar{X}$ =2.41 S^2= .75	$\bar{X}$ =2.62 S^2= .42	$\bar{X}$ =2.42 S^2= .47	$\bar{X}$ =2.00 S^2= .82
LOW	3	$\bar{X}$ =1.22 S^2= .86	$\bar{X}$ = .32 S^2= .32	$\bar{X}$ = .29 S^2= .28	$\bar{X}$ = .64 S^2= .49	$\bar{X}$ = .06 S^2= .06	$\bar{X}$ = .08 S^2= .10
	4	$\bar{X}$ =1.53 S^2= .86	$\bar{X}$ - .78 S^2= .71	$\bar{X}$ =1.00 S^2= .82	$\bar{X}$ = .92 S^2= .74	$\bar{X}$ = .35 S^2= .35	$\bar{X}$ = .33 S^2= .38
	5	$\bar{X}$ =2.58 S^2= .53	$\bar{X}$ =2.40 S^2= .70	$\bar{X}$ =1.71 S^2=1.03	$\bar{X}$ =1.88 S^2=1.13	$\bar{X}$ =1.60 S^2=1.03	$\bar{X}$ =1.05 S^2=1.05
		GRADE THREE			GRADE FIVE		

VARIANCES AND ERROR MEANS
PER CONDITION FOR GRADES THREE AND FIVE